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| (21) International Application Number: PCT/DK98/00022 (22) International Filing Date: 19 January 1998 (19.01.98) (30) Priority Data: 0059/97 17 January 1997 (17.01.97) DK (71) Applicant (for all designated States except US): NKT CABLES A/S [DK/DK]; NKT Allé 1, DK-2605 Brøndby (DK). (72) Inventors; and (75) Inventors/Applicants (for US only): PROCIDA, Inger, Margrethe [DK/DK]; Brønlunds Allé 46, DK-2900 Hellerup (DK). HANSEN, Bo, Svarrer [DK/DK]; Bolbro Villavej 8, DK-2960 Rungsted (DK). (74) Agent: HOFMAN-BANG & BOUTARD, LEHMANN & REE A/S; Hans Bekkevolds Allé 7, DK-2900 Hellerup (DK). | | (81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>In English translation (filed in Danish).</i> |
| (54) Title: ELECTRIC CABLE (57) Abstract The present invention relates to an electric underwater cable comprising one or more conductors being surrounded by solid insulating material. The insulating material is impregnated with a dibenzyl toluene (DBT) oil. The cable is particularly suited for use at great and/or varying depths, as the cable is distinguished by a particularly good stability against pressure impacts and thermal variations. | | |

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Electric cable

The present invention relates to an electric cable for laying out under ground or under water. The invention in particular relates to an electric underwater cable which is particularly suited for laying out at great sea depths.

Electric cables, e.g. in the form of underwater cables, normally consist of one or more conductors which separately or together are surrounded by a solid insulating material being impregnated with a dielectric fluid, such as an oil. Such electric cables are normally designated O.F. cables (O.F. = oil filled).

Electric cables being buried under ground or in the form of underwater cables are normally very long and not readily accessible once they have been buried/laid out. Further, the cables are often exposed to thermal variations and high pressure impacts. The latter are in particular important in connection with underwater cables. Consequently, it is important that the cables have good stability towards these pressure impacts, and that the cable is capable of resisting these thermal variations to which they may be exposed in use, so that the cable may have a long service life without essential risk of leakage, rupture or compression of the cable.

DK patent specification No. 156 453 discloses an electric underwater cable of the above kind. The underwater cable disclosed therein is especially characterized in that 1-methyl naphthalene is used as dielectric fluid. 1-methyl naphthalene is suspected of being carcinogenic, and consequently it would be most unfortunate if such a cable were to spring a leak.

Leakage on such oil filled cables is very rare, but if it happens it is very important that the oil spilled is as little toxic as possible. The oils in the known O.F. cables described above do not meet this requirement, and
5 it is thus expedient to find another oil for use in such cables, which oil is biodegradable and essentially harmless to micro-organisms in the ground or marine organisms.

It is the object of the present invention to devise an
10 electric cable of the kind stated in the preamble, which at least has the same good properties as the cable disclosed in DK patent No. 156 453, and where the oil used is biodegradable and essentially harmless to micro-organisms in the ground and marine organisms in case of
15 spillage of the oil.

It has now surprisingly turned out that an electric cable, such as an underwater cable comprising one or more conductors surrounded by a solid insulating material being impregnated with an insulating oil, where dibenzyl
20 toluene (DBT) is used as oil, meets this requirement, as DBT surprisingly has turned out to be biodegradable, harmless to marine organisms, micro-organisms in the ground, and other biological organisms, and further DBT does not accumulate in the food chain. In addition, the
25 DBT-oil is essentially insoluble in water, and in case of spillage from an underwater cable, the oil will sink to the sea floor from where, if desired, it may be removed by simple methods, e.g. suction.

As criterion for the choice of the oil which is disclosed
30 in DK patent No. 156 453 it is i.a. mentioned that it is very essential that the oil has a sufficiently low viscosity at the temperatures of use for it to be able to follow cycles with expansion and contraction due to

thermal variations of the cable. Further, it is in particular necessary that the viscosity of the insulating oil must be sufficiently low for the oil, at any temperature to which the cable might be exposed, to be
5 sufficiently flowable to be able to move along the cable and thereby constantly maintain the solid insulating material of the cable totally impregnated.

Other important criteria include that the oil must not have too high volatility. Further, the oil must possess
10 good insulating properties, a low dielectric loss factor, and a good gas absorption capacity. The oil must not tend to separate solid paraffinic products at the lowest temperatures of use of the cable, and when used in underwater cables the oil must further have a density which is
15 close to or equal to the density of the surrounding water.

The cable disclosed in DK patent No. 156 453 reasonably fulfils these criteria. If the cable is used at very great depths, and in particular at varying depths, there
20 is, however, a certain tendency for the cable to get compressed so that the insulating property in these flattened areas is insufficient.

Thus, it is a further object of the present invention to devise an electric underwater cable of the kind stated in
25 the preamble, which at least has the same good properties as the cable disclosed in DK patent No. 156 453, and which preferably has increased security against compression when used at great sea depths.

Thus, it has further turned out that an electric underwater cable comprising one or more conductors surrounded
30 by solid insulating material being impregnated with an insulating oil, where dibenzyl toluene (DBT) is used as oil, has particularly good properties as compared with

the properties of the known underwater cables, in particular as regards the ability to resist local compressions.

Underwater cables and other oil-carrying cables according to the present invention thus comprise an insulating oil which preferably consists of pure dibenzyl toluene oil. The oil may, however, comprise minor amounts of impurities provided these impurities essentially do not change the flow properties and density of the dibenzyl toluene oil. In another embodiment, the oil comprises one or more of the alkylated hydrocarbons dibenzyl toluene, benzyl-methylbenzyl-benzene and ditolyl phenyl methane. The total amount of these other alkylated hydrocarbons preferably constitutes less than 20 weight-%, and in particular less than 10 weight-%.

The dibenzyl toluene oil can consist of one single isomer, but in view of viscosity and density it is preferred that the dibenzyl toluene oil is in the form of a mixture of two or more isomers. Such mixtures flow more easily in a cable, and thus the oil is even more able to follow cycles with expansion and contraction due to thermal variations of the cable, and to be able to move along the cable and thereby constantly maintain the solid insulating material of the cable totally impregnated. Further, it should be mentioned that such isomeric mixtures of dibenzyl toluene oil are significantly cheaper than pure isomers of this oil.

Table 1 shows some essential physical properties of insulating oils which have been used or contemplated for use in O.F. cables, and the corresponding properties for DBT. The physical properties for the naphthalene derivatives have been taken from Beilstein "HANDBUCH DER ORGANISCHEN CHEMIE" (Vierte Auflage).

TABLE 1

| Oil | Melting point (°C) | Density at 20 °C (g/cm ³) | Viscosity at 20 °C (cSt) |
|-----------------------------------|-----------------------|--|-----------------------------|
| 1-methyl naphthalene | -30 | 1.020 | 3.5 |
| 1-ethyl naphthalene | -15 | 1.008 | 4.1 |
| 2-ethyl naphthalene | - 7 | 0.993 | 2.9 |
| 1-propyl naphthalene | -12 | 0.992 | 4.9 |
| 1-butyl naphthalene | -20 | 0.975 | 6.5 |
| 2-butyl naphthalene | - 5 | 0.970 | 4.75 |
| 2-tert.butyl naphthalene | - 4 | 0.970 | - |
| 1-pentyl naphthalene | -22 | 0.966 | - |
| 1,3-dimethyl naphthalene | - 4 | 1.006 | - |
| 1,6-dimethyl naphthalene | -14 | 1.003 | - |
| 1,2,3,4-tetrahydro naphthalene | -36 | 0.970 | 2.2 |
| 2-pentyl naphthalene | - 4 | 0.956 | - |
| Dibenzyl toluene | -27 | 1.040 | 30.,0 |

As appears from the above table, the dibenzyl toluene oil
 5 has a particularly high viscosity as compared with the
 other oils, and further the dibenzyl toluene oil has a
 somewhat higher density and consequently also a density
 which is higher than the density of the surrounding water
 in which the cable is laid out.

10 Thus it is very surprising that electric underwater
 cables according to the invention have a significantly
 improved stability against pressure impacts and thermal
 variations as compared with known electric underwater
 cables with insulation comprising other of the oils
 15 mentioned in table 1.

In a particularly preferred embodiment of the invention, the electric cable comprises a solid insulating material in the form of cellulose. It is particularly preferred that the solid insulating material is in the form of paper wound round the conductor or conductors.

An electric cable according to the present invention may comprise one or more conductors having the same or different size. The number of and the diameter of conductors depend on how much power the cable is to conduct. It is particularly preferred that the cable according to the invention comprises one or more conductors which preferably each of them may have a diameter of up to about 5 cm.

The conductor or conductors may be formed from various materials, such as e.g. twisted copper or aluminium wires.

If the electric cable according to the present invention comprises two or more conductors it is preferred that the cable comprises at least one longitudinally progressing duct which essentially is filled with dibenzyl toluene. Hereby a more rapid and more easy distribution of the oil is obtained.

Underwater cables according to the present invention may advantageously be provided with an outer sheath in the form of a bendable sheath of e.g. plastic and/or metal being resistant to sea water.

In a first particularly preferred embodiment, the cable according to the invention comprises a centrally positioned conductor of an electrically conductive material, such as copper. The conductor is surrounded by a solid insulating material in the form of paper being wound round the conductor. The paper layer surrounding

the conductor has a thickness of preferably 1-5 cm and is impregnated with dibenzyl toluene oil. The cable further has a lead sheath and an outer sheath which optionally may be of polyethylene.

- 5 In a second preferred embodiment, the cable according to the invention comprises 2 or 3 conductors which each separate one is surrounded by a solid insulating material in the form of paper being wound round the conductor. The paper layer surrounding the conductor has a thickness of
10 preferably 1-5 cm and is impregnated with dibenzyl toluene oil. The cable further has a common lead sheath and outer sheath which e.g. may be of polyethylene. Further, the cable is characterized by being flat, as the conductors, if there are more than 2, preferably are
15 placed side by side. Furthermore, the cable is self-compensating.

EXAMPLES:

- The effect of the DBT-oil on marine organisms was studied. *Skeletonema costatum* and *Acartia tonsa* were
20 exposed to sea water saturated with ¹⁴-C labelled DBT (about 16 µm/l) and solutions thereof for 72 h and 48 h, respectively. The result of this experiment showed that the mortality (50% dead) of *Skeletonema costatum* and *Acartia tonsa* required a DBT concentration which is
25 higher than the solubility of the oil in water.

- The biodegradability of the DBT-oil was tested according to OECD guideline No. 306. The test results showed that the oil is biodegradable and is not accumulated in the food chain. The degradation of the DBT-oil will, because
30 of methyl-bridges between the aromatic rings, not result in PAH-like molecules, but in smaller, increasingly more easily degradable molecules.

C l a i m s :

1. An electric cable comprising one or more conductors surrounded by solid insulating material being impregnated
5 with an insulating oil, c h a r a c t e r i z e d in that the oil is pure dibenzyl toluene (DBT), dibenzyl toluene containing a minor amount of impurities, where the amount of impurities essentially does not change the viscosity and density of the dibenzyl toluene oil, or a
10 mixture of dibenzyl toluene and one or more of the alkylated hydrocarbons dibenzyl toluene, benzyl-methylbenzylbenzene and ditolyl phenyl methane, where the alkylated hydrocarbons preferably do not constitute more than up to 20 weight-% of the insulating oil.
- 15 2. An electric cable according to claim 1, c h a r a c t e r i z e d in that the cable is an underwater cable.
3. An electric cable according to claim 1 or 2, c h a r a c t e r i z e d in that the oil is a mixture of two or more isomers of dibenzyl toluene (DBT).
- 20 4. An electric cable according to claim 1, 2 or 3, c h a r a c t e r i z e d in that the solid insulating material is cellulose, preferably in the form of paper being wound round the conductor or conductors.
5. An electric cable according to any of the claims 1-4,
25 c h a r a c t e r i z e d in that the cable comprises 1 or more conductors.
6. An electric cable according to any of the claims 1-5, c h a r a c t e r i z e d in that the cable comprises at least one longitudinally progressing duct which
30 essentially is filled with insulating oil.

7. Use of dibenzyl toluene as insulating oil in electric cables, preferably in electric underwater cables.

8. Use of an electric cable comprising one or more conductors surrounded by solid insulating material being
5 impregnated with an isolating oil selected from pure dibenzyl toluene (DBT), dibenzyl toluene containing a minor amount of impurities, where the amount of impurities essentially does not change the viscosity and density of the dibenzyl toluene oil, or a mixture of
10 dibenzyl toluene and one or more of the alkylated hydrocarbons dibenzyl toluene, benzyl-methylbenzylbenzene and ditolyl phenyl methane, where the alkylated hydrocarbons preferably do not constitute more than up to 20 weight-% of the insulating oil, for laying out on the
15 sea floor.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/DK 98/00022

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01B 3/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

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WPI, CAPLUS, PAJ

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☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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02/04/98

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